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Formal Method Mod. 2 (Model Checking)

Laboratory 12

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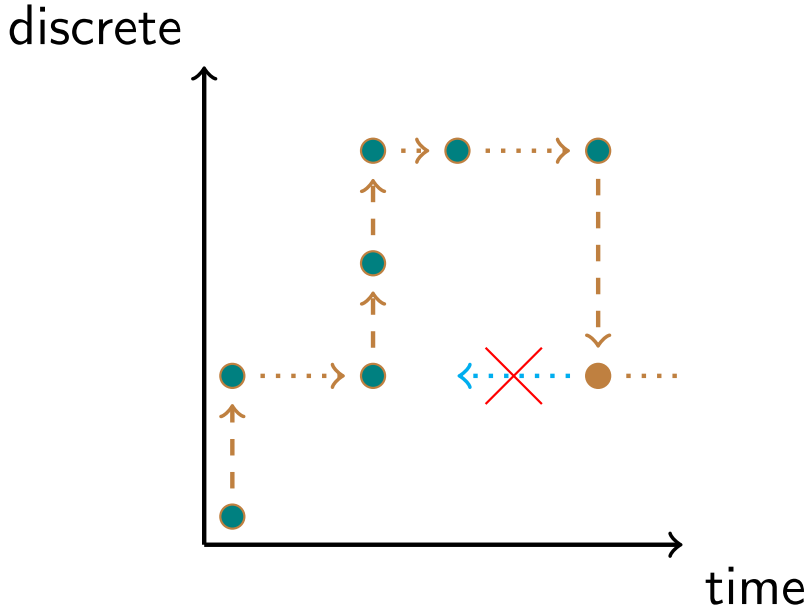
Hybrid systems

Cyber-physical systems

- Discrete controller with some modes: (in)finite state automaton; e.g. electronic controller.
- `continuous` variables with some behaviour w.r.t. time, physical phenomena e.g. braking car, water pump, temperature.

- in general model checking on hybrid systems is **undecidable**.
- many sub-classes
  - decidable: *rectangular*, *singular*;
  - undecidable: *linear*;



Hybrid systems: representation

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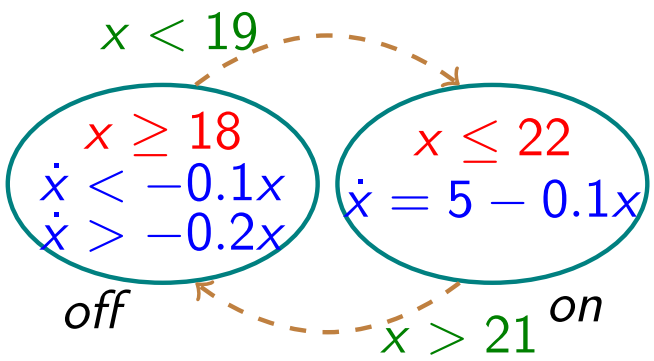
Hybrid Automata

- Explicit graph representation of discrete states/modes (nodes) and transitions (edges);
- Symbolic representation of linear temporal aspects via polytopes (N dimensional polyhedron);
- location invariants,
- transition guards,
- flow: derivative w.r.t time.



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Outline

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HyComp introduction

- HyComp has been developed in Embedded Systems (FBK) as part of Sergio Mover's PhD.
- Supports the modelling and verification of a network of hybrid automata;
- Supports invariant and LTL properties;
- It encodes the Hybrid model into a "standard" nuXmv model.

HyComp: input language [1/3]

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The input language of HyComp is called HyDi (Hybrid automata with Discrete interaction).

Overview

- `main` module contains description of the network of automata: processes are `MODULE` instances;
- `main` module contains synchronization constraints: `EVENT`;
- Symbolic description of infinite transition system using: `INIT`, `INVAR` and `TRANS` to specify initial, invariant and transition conditions.
- `continuous` type variables with `FLOW` conditions,

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HyComp: input language [2/3]

HyComp adds

- `continuous` variable type;
- all `continuous` vars increase accordingly to their `FLOW` conditions in timed transitions;
- `time`: built-in `continuous` symbol with flow condition: `der(time) = 1`, can not be used in properties;
- `URGENT`: freeze time: when one of the `URGENT` conditions is satisfied only discrete transitions are allowed;

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HyComp: input language [3/3]

HyComp updates

- `TRANS` constrain the discrete behaviour only,
- `INVAR`: `continuous` allowed in invariants with shape: `no_continuous_expr -> convex_continuous_expr`.

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HyComp: commands

read and rewrite model

1. `hycomp_read_model`
2. `hycomp_compile_model`
3. `hycomp_untime_network`
4. `hycomp_async2sync_network`
5. `hycomp_net2mono`

check specifications

- `hycomp_check_invar_*`
- `hycomp_check_ltl*`

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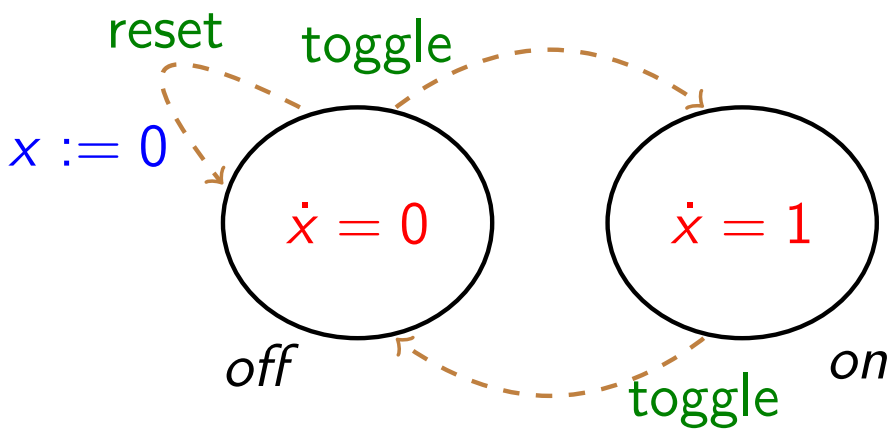
Example: stopwatch [1/3]

- write a HyDi model that represents the hybrid automaton in the picture.
- add an asynchronous process that controls the stop-watch using the `toggle` and `reset` commands.



Example: stopwatch [2/3]

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Stopwatch module

```
MODULE StopWatch
DEFINE
  on  := mode = _on;
  off := mode = _off;

VAR
  mode : {_on, _off};
  c : continuous;

EVENT toggle, reset;
FLOW on -> der(c) = 1;
FLOW off -> der(c) = 0;

TRANS EVENT = reset -> next(c) = 0;
TRANS EVENT != reset -> next(c) = c;
TRANS EVENT = toggle -> next(mode) != mode;
```

Example: stopwatch [3/3]

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Controller module

```
MODULE Controller
EVENT toggle, reset;
```

main module

```
MODULE main
VAR
  stopWatch : StopWatch;
  controller : Controller;

SYNC controller, stopWatch EVENTS toggle, toggle;
SYNC controller, stopWatch EVENTS reset, reset;
```

Outline

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Bouncing ball

- A ball is initially at height 10.
- We let the ball fall and bounce.
- Every time the ball bounces half its speed is lost.
- The gravitational acceleration is 9.8.

Timed thermostat

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- a thermostat has 2 states: *on* and *off*;
  - if the temperature is below 18 degrees the thermostat switches *on*.
  - if the temperature is above 18 degrees the thermostat switches *off*.
- Every time the thermostat misure the temperature in the room, the temperature increases (if *on*) or decreases (if *off*) by *dt* (with respect to the previous check);
- the thermostat measures the temperature at most ($<$) every max_dt time units.
- the temperature initially is in $[18 - max\_dt; 18 + max\_dt]$.

Verify that the temperature is always in $[18 - 2max\_dt; 18 + 2max\_dt]$